Influence from Straw on Performance of Cement Insulation Mortar Using Mud from Washing Manufactured Sand

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Abstract. Insulation mortar was prepared with cement, mud from washing manufactured sand, wheat straw, vitrified microbead, polypropylene fibre and chemical admixture. Influence law of wheat straw on performance of cement insulation mortar was discussed. Influence factors included pretreatment method, dosage and length of straw. Features of straw surface pretreated by NaOH solution and bonding interface were observed by scanning electron microscopy. Dry density, compressive strength, thermal conductivity coefficient reduce with the increase of straw length and the decrease of soak time. When straw dosage increases, they decrease firstly, increase later. Straw reduces the mass loss of cement insulation mortar treated at temperature below 500℃. Straw surface pretreated by NaOH solution becomes rough. There are trenches with widths about a few microns. It makes a better interface combination between straw and cement matrix.

Keywords: Insulation mortar; Mud; Straw; Performance; Interface.

1. Introduction

The combination of porous straw and cement insulation mortar can effectively reduce building energy consumption. However, some studies have shown that the extractive product from straw in the high-alkaline environment will delay the setting and hardening process of Portland cement; Fiber depolymerization forms a large number of connected pores, which makes the interface between cement matrix and straw have micro-cracks; The waxy layer on the straw surface reduces the interfacial bond strength [1-5]. In order to improve the interface bonding ability between the wheat straw and the cement matrix, the straw was soaked in NaOH solution, and the influence of pretreatment method. Straw dosage and length on the performance of cement insulation mortar were studied through a series of experiments. SEM was used to observe the surface of the straw after pretreatment and the bonding interface between the straw and the cement matrix.

2. Test raw materials and mix ratio of cement matrix

2.1 Raw material

(1)Wheat straw. Wheat straw was selected for the experiment. Wheat straw was cut to the certain length, then soaked in 3.5% NaOH solution for 12h or 24h.Then it was cleaned with water, and dried.

(2)42.5 grade ordinary Portland cement. The initial setting time of the cement was 199min, and the final setting time was 243min. The compressive strength and flexural strength of the 28d mortar were 52.4MPa and 9.82MPa.

(3)Vitrified microbead. Particle size was 0.5~1.5mm, density was 80~130kg/m^3, thermal conductivity was 0.032~0.045W/(m·K).

(4)Dispersible emulsion powder. The average particle size was 80μm, and the viscosity of 50% solution was 0.5~2.0Pa·s.

(5)Polypropylene fibre. The nominal length was 6~40mm, the melting point was 160~180°C, the density was 0.91g/cm^3, the elastic modulus was 4800MPa, and the elongation at break was 17%.

(6)Cellulose ether. Methoxy content was 28.0%~30.0%, hydroxypropoxy content was 7.5%~12.0%.

(7)Air entraining agent. The anionic liquid air entraining agent was selected, the foaming ratio was 27 times, the bleeding rate was 65% at 1h.

(8)Mud from washing manufactured sand. It contained a large number of clay. After heat treatment at 600~750°C, its activity coefficient reached more than 75%, which could be used as mineral admixture to replace part of the cement to prepare insulation mortar.

2.2 Mix ratio

Different straw soaking time, straw dosage and length were selected as the main influencing factors. the mix ratio of insulation mortar was shown in Table 1, and the heat-treated mud replaced 10% cement. When the variable was soaking time of straw in NaOH solution, the soaking time was 12h and 24h, and the mix ratio of insulation mortar was the mix ratio No. 2 in Table 1. When the variable was straw dosage, 1.0%, 2.0%, 3.0%, 4.0% and 5.0% of the amount of vitrified microbead were selected, and the mix ratios of insulation mortar were the mix ratio No. 1-5 in Table 1. When the variable was straw length, the length was selected as 3mm, 7mm, 11mm and 15mm, and the mix ratios of insulation mortar were No. 6, 2, 7 and 8 in Table 1.

Table 1. Mix ratio of insulation mortar

Mix No.	Cement /g	Heat-treated mud/g	Vitrified microbead/g	Water /g	Air entraining agent/g	Emulsion powder/g	Fiber /g	Straw dosage /%	Straw length /mm
1	855	95	746	1045	3.71	38	6.65	1.0	7
2	855	95	746	1045	3.71	38	6.65	2.0	7
3	855	95	746	1045	3.71	38	6.65	3.0	7
4	855	95	746	1045	3.71	38	6.65	4.0	7
5	855	95	746	1045	3.71	38	6.65	5.0	7
6	855	95	746	1045	3.71	38	6.65	2.0	3
7	855	95	746	1045	3.71	38	6.65	2.0	11
8	855	95	746	1045	3.71	38	6.65	2.0	15

3. Experimental study on the influence of straw on the performance of insulation mortar

3.1 Influence on compressive strength, dry density and thermal conductivity

3.1.1 Different pretreatment methods of straw

When straw was soaked in a 3.5% NaOH solution for 12 hours and 24 hours, the measured 28 day dry density, compressive strength, and thermal conductivity coefficient of the insulation mortar were shown in Table 2. As shown in Table 2, when the soaking time is 12 hours, the dry density, compressive strength, and thermal conductivity coefficient are 452kg/m^3, 2.77MPa, and 0.027W/(m·K), respectively. When the soaking time is 24 hours, the dry density, compressive strength, and thermal conductivity coefficient increase to 470kg/m^3 2.85MPa and 0.032W/(m·K), respectively. This is mainly because as the soaking time of straw increases, the wax layer can dissolve more thoroughly, making the straw and mortar bond more tightly. Dry density, compressive strength, and the thermal conductivity coefficient also slightly increases accordingly.

Table 2. Dry density, compressive strength and thermal conductivity coefficient of insulation mortar under different straw soaking time

Mix No.	Soaking time /h	Dry density/(kg/m^3)	Compressive strength/MPa	Thermal conductivity coefficient/[W/(m·K)]
2	12	452	2.77	0.027
2	24	470	2.85	0.032

3.1.2 Different straw dosage

The dry density, compressive strength and thermal conductivity coefficient of insulation mortar measured at 28d age were shown in Table 3 when the dosage of straw was changed. As can be seen from Table 3, when the straw dosage increases from 1.0% to 5.0%, the dry density of insulation mortar first decreases from 494kg/m^3 to 470kg/m^3, and then increases to 507kg/m^3; The compressive strength first decreases from 3.11MPa to 2.46MPa, and then increases to 2.92MPa; The thermal conductivity decreases from 0.038W/(m·K) to 0.025W/(m·K), and then increases to 0.029W/(m·K). Therefore, with the increase of straw dosage, the dry density, compressive strength and thermal conductivity coefficient of insulation mortar decrease first, and then increase. This is the result of the joint action from the following two effects: (1) Straw is a kind of material with light weight and more pores, adding a certain amount of straw can reduce the dry density, compressive strength and thermal conductivity coefficient of insulation mortar; (2) With the increase of straw dosage, the specific surface area of insulation mortar increases, and the viscosity increases, resulting in a decrease in the foaming effect of the air entraining agent, a decrease in the introduction of bubbles, an increase in mortar compactness, and an increase in dry density, compressive strength and thermal conductivity coefficient.

Table 3. Dry density, compressive strength and thermal conductivity coefficient of insulation mortar under different straw dosage

Mix No.	Straw dosage /%	Dry density /(kg/m^3)	Compressive strength/MPa	Thermal conductivity coefficient/[W/(m·K)]
1	1.0	494	3.11	0.038
2	2.0	470	2.85	0.032
3	3.0	475	2.46	0.028
4	4.0	482	2.49	0.025
5	5.0	507	2.92	0.029

3.1.3 Different straw lengths

The measured 28d dry density, compressive strength, and thermal conductivity coefficient after changing the length of the straw were shown in Table 4. From table 4, it can be seen that the length of straw increases from 3mm to 15mm, the dry density gradually decreases from 489kg/m^3 to 437kg/m^3, and the compressive strength gradually decreases from 2.91MPa to 2.48MPa, the thermal conductivity coefficient gradually decreases from 0.037W/(m·K) to 0.021W/(m·K).Therefore, with the increase of straw length, the dry density, compressive strength and thermal conductivity coefficient of insulation mortar gradually decrease, and the insulation performance increases. The main reasons are as follow: the total mass of the straw is certain, and the specific surface area and the viscosity of the mortar are reduced when the length increases; the foaming effect of the air entraining agent is increased, and the dry density, compressive strength and thermal conductivity coefficient of the insulation mortar are reduced.

Table 4. Dry density, compressive strength and thermal conductivity coefficient under different straw lengths

Mix No.	Straw length /mm	Dry density /(kg/m^3)	Compressive strength/MPa	Thermal conductivity coefficient /[W/(m·K)]
6	3	489	2.91	0.037
2	7	470	2.85	0.032
7	11	455	2.63	0.026
8	15	437	2.48	0.021

3.2 Influence on high temperature resistance

After the standard curing for 28d, the insulation mortar specimens was put into the high-temperature electric furnace for high-temperature treatment. The heating rate was adjusted to 10℃ per minute and the setting maximal temperature(200℃, 300℃, 400℃ and 500℃ respectively) was maintained for 1h, and then cooled to room temperature. The mass and compressive strength of the insulation mortar were tested, and the loss rates of mass and compressive strength caused by high-temperature treatment were calculated. The loss rates of mass and compressive strength of the insulation mortar were shown in Figure 1 and Figure 2.

As can be seen from Figure 1, as the treatment temperature increases from 200℃ to 500℃, the mass loss rate of insulation mortar without straw gradually increases from 11.6% to 17.9%, and the mass loss rate of insulation mortar with 2.0% straw gradually increases from 9.1% to 16.2%. The test results show that the mass loss rate of insulation mortar increases when the treatment temperature increases within a certain range, but the addition of straw can reduce the mass loss rate. The possible reason is: because the straw contains a large number of fibers, it has a limiting effect on the cracking and spalling of mortar at high temperature, thereby reduces the mass loss.

As can be seen from Figure 2, as the treatment temperature increases from 200℃ to 500℃, the compressive strength loss rate of the insulation mortar without straw gradually increases from 13.5% to 40.5%, and the compressive strength loss rate of the insulation mortar with 2.0% straw gradually increases from 13.5% to 49.9%. The test results show that the compressive strength loss rate increases when the treatment temperature increases within a certain range, but the addition of straw increases the compressive strength loss rate. The possible reason is: the addition of straw leads to inconsistent deformation due to temperature change at interface between the straw and the cement matrix, exacerbates the compressive strength loss.

4. Microstructure analysis

Scanning electron microscopy was used to observe the surface of the straw after soaking in NaOH solution, and the results were shown in Figure 3. It can be seen from Figure 3 that the waxy layer on the surface of the straw treated with NaOH solution is destroyed. The surface becomes rough, and many grooves with the width about a few microns are generated.

Scanning electron microscopy was used to observe the interface between straw and cement matrix, and the results were shown in Figure 4. The interface between is closely combined, and no cracks exists. The rough surface of the straw after soaking in NaOH solution enhances the adhesion ability with the cement matrix, and the bonding effect between the straw and the cement matrix can be improved.

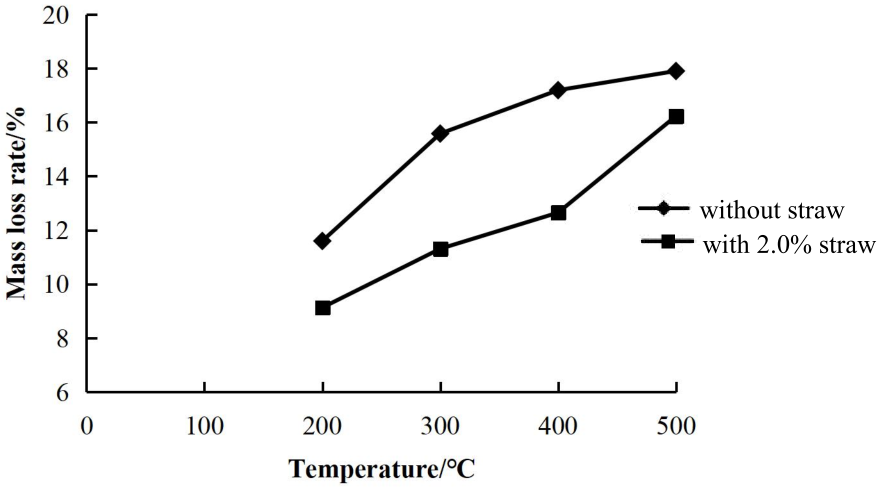

Figure 1. Mass loss rate at different treatment temperatures

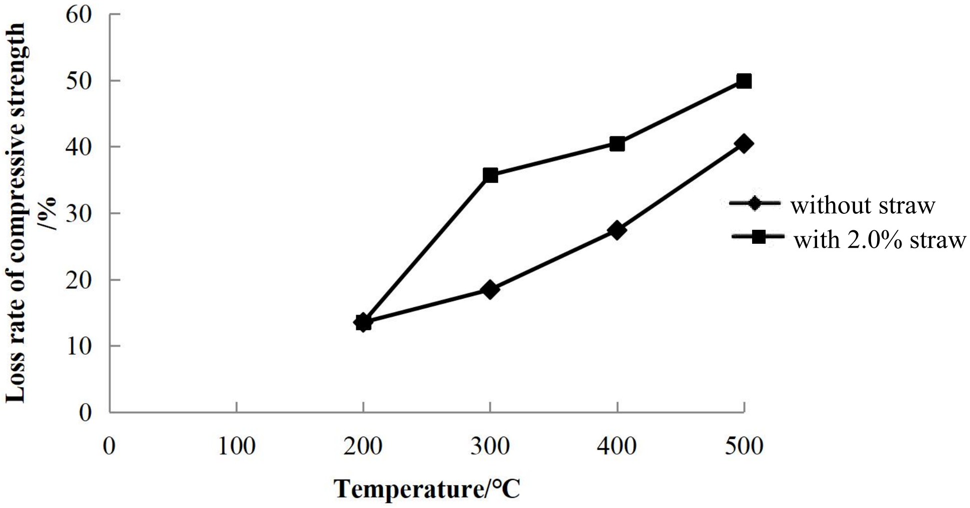

Figure 2. Loss rate of compressive strength at different treatment temperatures

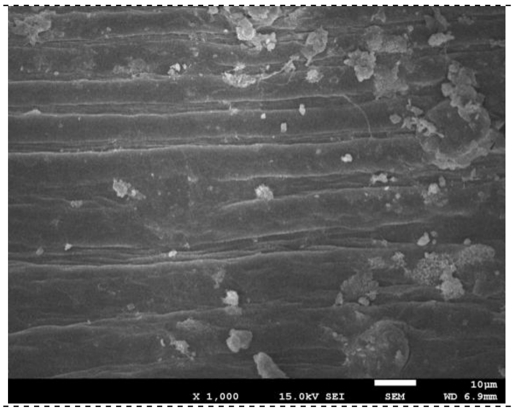

Figure 3. Surface morphology of straw treated with NaOH solution

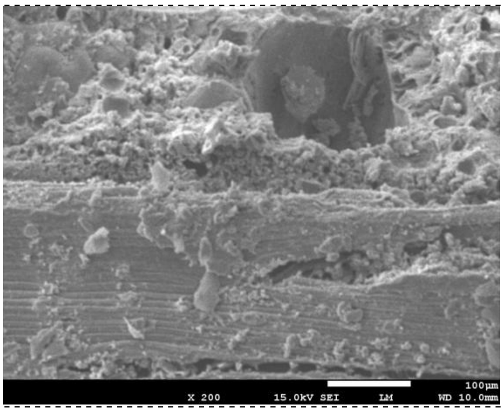

Figure 4.Interface morphology between straw and cement matrix

5. Conclusions

With the increase of straw length and the decrease of soaking time of NaOH solution, the dry density, compressive strength and thermal conductivity coefficient of insulation mortar decrease. With the increase of straw dosage in the range of 1.0%~5.0%, the dry density, compressive strength and thermal conductivity coefficient decrease first, and then increase.

The higher the treatment temperature, the greater the loss rates of the mass and compressive strength of the insulation mortar, and the addition of straw is beneficial to reduce the loss rate.

After being treated with NaOH solution, the waxy layer on the straw is broken and the surface becomes rough, and there are grooves about a few microns width, which enhance the adhesion ability with the cement matrix and improve the interface bonding effect.

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